Dec. 8, 1970 P. BURNS 3,546,450

APERTURE DEVICES FOR MASS SPECTROMETERS

Filed Dec. 26, 1967 3 Sheets-Sheet 1

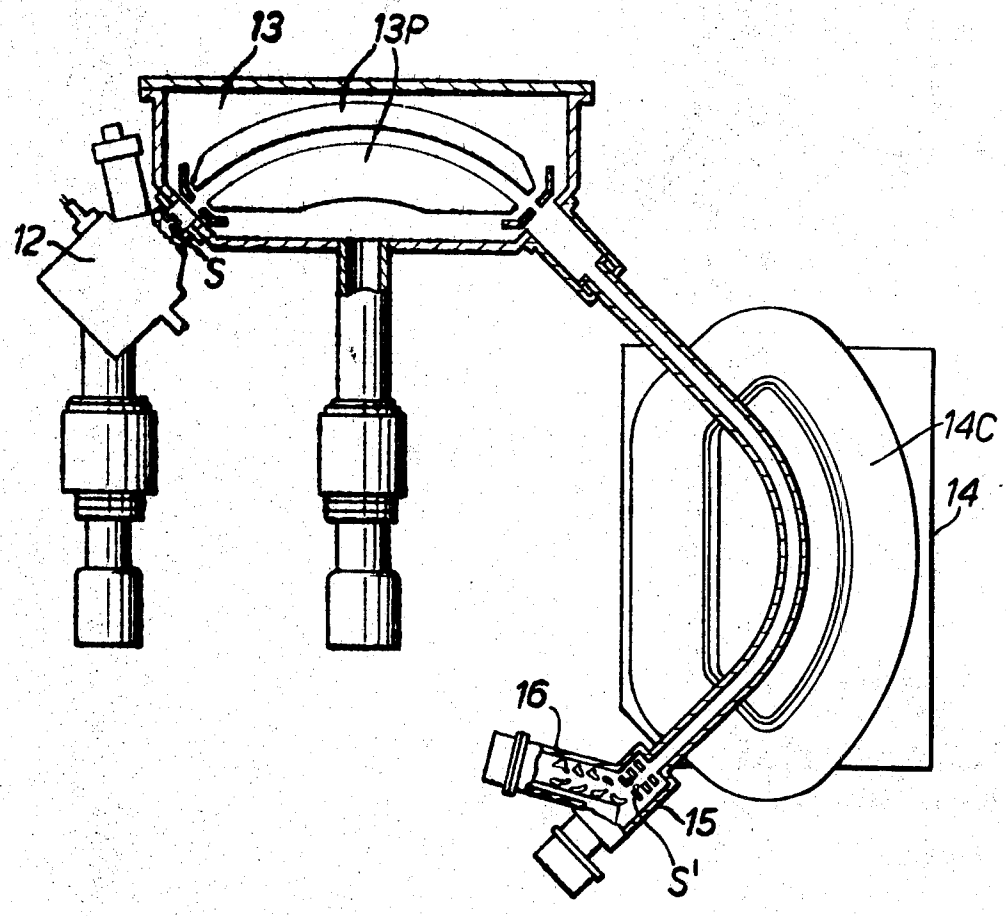


Fig. 1

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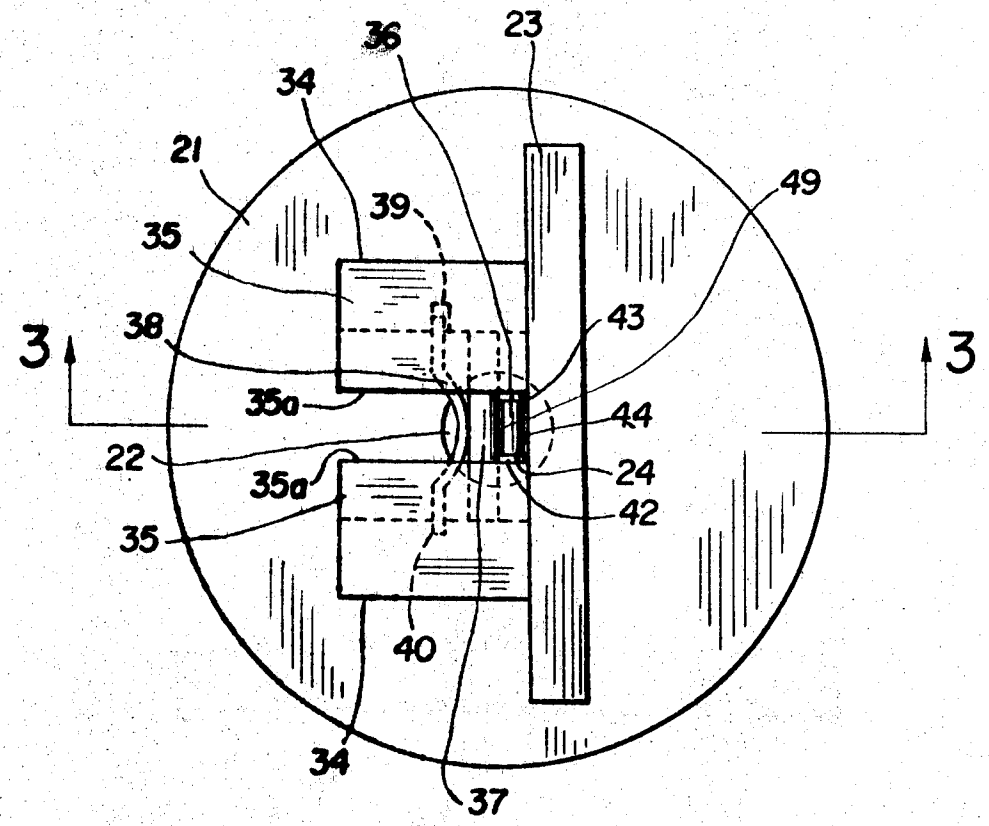


Fig. 2

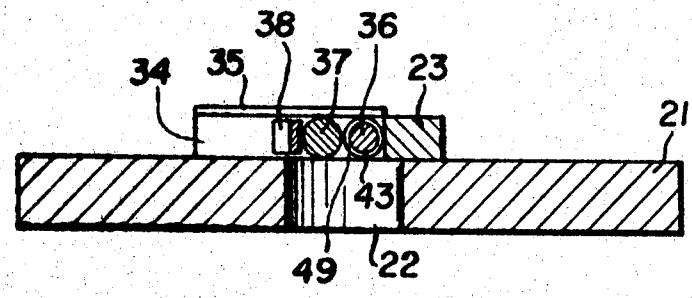


Fig. 3

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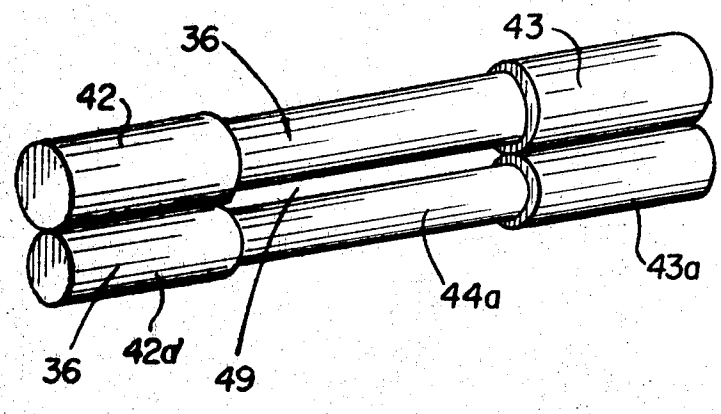


Fig. 4

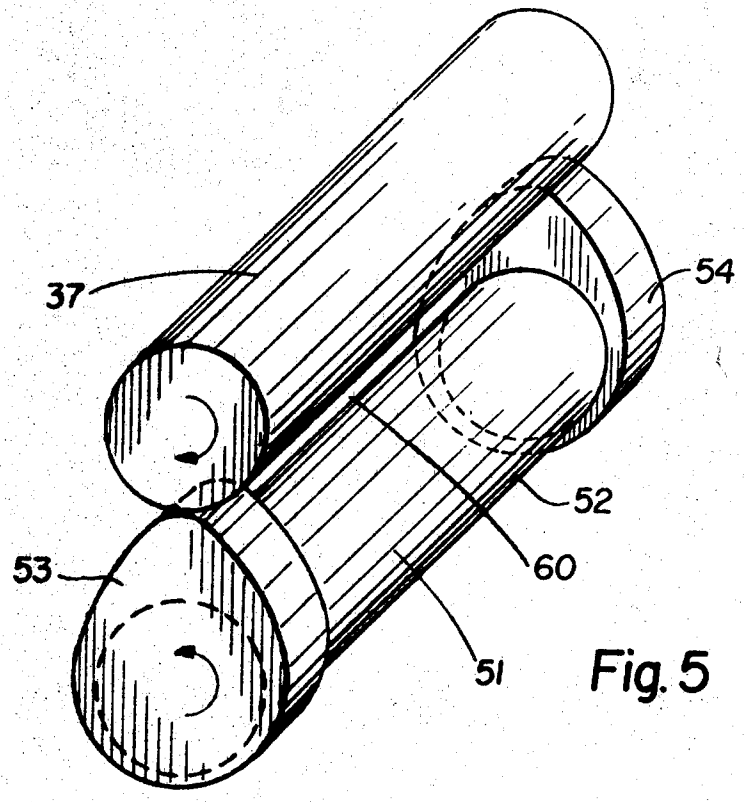


Fig. 5

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APERTURE DEVICES FOR MASS SPECTROMETERS

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Int. Cl. H01j *39/34*
U.S. Cl. 250—41.9 12 Claims

ABSTRACT OF THE DISCLOSURE

An aperture device of a mass spectrometer, comprising a pair of parallel, cylindrical slit-forming members. One of the members has, adjacent each end, an enlarged portion which is circumferentially continuous and abuts the other member of the pair, thereby maintaining respective central portions of the members in spaced, at least two slit-forming relationship. The enlarged portions can be coaxial cylinders or can be of cam-form cross section so that on rotation of the one member, the width of the slit will be changed.

CROSS-REFERENCED PATENT

United States Letters Patent 3,187,179 issued June 1, 1965 to R. D. Craig et al., entitled "Variable Slit Systems for Mass Spectrometer Ion Sources."

BACKGROUND OF THE INVENTION

The field of the invention

This invention relates to mass spectrometers and more particularly to a mass spectrometer equipped with a novel and improved slit structure.

Mass spectrometry is a known method of testing a material to ascertain its composition. In a mass spectrometer, a material being analyzed is first ionized in an ionization chamber. Ions are propelled from the ionization chamber through a source slit. The ions pass through the source slit into an analyzer region where they are deflected. Focused ones of the ions pass through a collector slit to a suitable detecting and/or recording mechanism.

The deflection of the ions in the analyzer region may be accomplished in either of two ways. In a so-called single-focusing instrument, a magnetic analyzer magnetically deflects the ions. In a so-called double-focusing instrument, an electrostatic analyzer is interposed between the ionization source and a magnetic analyzer so that ions are deflected and focused both electrostatically and magnetically.

While the present invention is equally applicable to either a single- or double-focusing instrument, it will be described in the environment of a double-focusing instrument. This environment has been selected because the double-focusing instrument has higher resolution capabilities than the single and the problems obviated by this invention are manifested most greatly in a high-resolution mass spectrometer.

The extent to which any given ion will be deflected depends upon its so-called mass-charge ratio, the charge applied to accelerating plates in the ionization source to propel the ion toward the collector and the intensities of the electrostatic and magnetic fields.

Since the amount of deflection of an ion is proportional to its mass-charge ratio, under a given set of conditions only certain ions will be focused. That is, only ions of certain characteristics will pass through the collector slit into the collecting and recording mechanism. Unfocused

ions either impinge on the walls defining the ion path through the analyzer region or impinge on the slit-defining structures. Accordingly, factors affecting the resolution achieved in any given structure are, then, the parallelism of the members defining the slit, their proper orientation perpendicular to the plane of ion deflection, and the spacing between the members.

As resolution characteristics of mass spectrometers have been improved, the slit structures have more and more become a limiting factor on the resolving power of the mass spectrometer. This is true both because of the very close tolerances which must be met for a high resolution slit structure and because, in use, deposits gradually collect on the slit structure which adversely affect the precision of the slit and therefore the resolving power of the instrument.

THE PRIOR ART

One highly-successful prior known slit structure is that disclosed and claimed in United States Letters Patent No. 3,187,179 issued June 1, 1965, to R. D. Craig et al. under the title "Variable Slit Systems for Mass Spectrometer Ion Sources." There, a pair of relatively adjustable slit-delineating members are positioned across the path of ion travel from the source. The defined slit is an elongated, thin passage which is located perpendicular to the plane in which the ions are deflected in the analyzer region.

While the slit structures shown in the referenced patent and other structures have been satisfactory, they have had limitations. These include complexity, difficulty in manufacture and they are not susceptible to simple replacement.

SUMMARY OF THE INVENTION

With the present invention, these listed and other prior disadvantages are overcome through the provision of a very pricse, yet inexpensive slit construction. In the preferred arrangement, a pair of precision cylindrical members are provided. These members may, for example, be cylindrical structures of the type normally used as roller contacts in a needle bearing.

In the preferred arrangement, one of the two members has a reduced-diameter, central, cylindrical portion. This central portion may be produced by removing metal in the central portion of a cylinder as by etching or lapping. Shaping of the surfaces by an electro-brightening process, sometimes referred to as anodic polishing, is also satisfactory. Preferably, however, enlarged end portions are provided through a precision electro-plating procedure.

With the preferred electro-plating system, layers of very fine precision can be developed for maintaining the two adjacent members in spaced relationship. For example, widths of from 50×10^{-6} inches to several thousandths of an inch can be developed. In addition, layers can be applied to both members if desired, and conversely, obviously, central portions of both members may be cut away if desired.

The two members are mounted in a suitable support and spring biased together so that their central portions define a very precise resolving slit. As the resolution capabilities of these members deteriorate in use, they may be rotated to provide fresh surfaces which precisely define the slit-delineating surfaces. When the two members no longer have the desired resolving power, they may be thrown away and a new pair of these inexpensive slit resolving members substituted.

According to one form of the invention, one of the members may be equipped with cam-like end portions. These cam-like portions are rotated to adjust the width of the slit and thereby provide not only an inexpensive, disposable slit structure, but an adjustable slit structure as well.

Accordingly, the objects of this invention are to provide a mass spectrometer equipped with novel and improved slit structure and novel and improved methods of making a slit structure.

Other objects and a fuller understanding of the invention may be had by referring to the following description and claims taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a diagrammatic sectional side elevation of a mass spectrometer embodying aperture devices according to the invention;

FIG. 2 is a plan view of an aperture device for a mass spectrometer on an enlarged scale;

FIG. 3 is a cross-sectional elevation of the aperture device as seen from the plane indicated by the line 3—3 of FIG. 2;

FIG. 4 is an enlarged perspective view of a pair of the slit-defining members; and,

FIG. 5 is an enlarged perspective view of an alternative pair of slit defining members.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 is a somewhat diagrammatic, partially sectioned, elevational view of a double-focusing mass spectrometer. The mass spectrometer includes an ion source **12** in which ions are liberated and from which the ions are propelled through a source slit S. The ions pass through an electrostatic analyzer **13** which has opposed conductive plates **13P**. A potential difference is maintained between the plates **13P**.

Ions are deflected by the electrostatic analyzer into a magnetic analyzer **14**. The magnetic analyzer is equipped with an electromagnetic coil **14C** which establishes a strong magnetic field transverse to the path of ions. The magnetic analyzer further deflects ions in the plane of the drawing of FIG. 1.

Focused ones of the ions pass through a collector slit S', into a collector **15**. In the disclosed mass spectrometer, an electron multiplier **16** is provided. The multiplier **16** provides an amplified output for recording the ions passing through the slit S'.

Referring now to FIGS. 2 and 3, the slit structure of this invention is shown in detail. The slit structure shown in FIGS. 2 and 3 is the slit structure used both as the source slit S and the collector slit S'. While the slit structure shown in FIGS. 2 and 3 is equipped with one cylindrical slit-defining member **37** and one slit-defining member **36** as shown in FIG. 4, either or both of the slit structures S, S' may be equipped with the modified slit-defining members of FIGS. 4 and 5.

The slit structures S, S' each have a base plate **21**. The disclosed base plate is an annulus which has an axially-disposed, central circular aperture **22**. A locating member **23** is secured to and supported by the base plate **21**. The locating member **23** has a planar slit-locating surface **24**. The plane of that slit-locating surface **24** is positioned such that it is parallel to the axis of the base plate and it locates a chord of the circular aperture **22**.

Two lateral spacers **34** project perpendicularly from the slit-locating surface **24** on opposite sides of the aperture **22**. Retaining plates **35** are attached to the spacers **34**.

The retaining plates **35** are spaced from one another and project toward one another from the spacers **34**. Opposed inner surfaces **35***a* of the retaining plates **35** are disposed in planes perpendicular to the locating surface **24**. These planes parallel the axis of the plate **21** and are spaced equally in diametrically opposite directions from the axis. These planes define chord segments of the aperture **22**.

The retaining plates **35**, the base plate **21**, the locating member **23** and the spacers **34** together define a mounting space. A pair of slit-defining members **36**, **37** are positioned in this space. The members **36**, **37** are biased against one another and against the locating surface **24** by a spring retainer **38**.

The spring retainer **38** projects into suitable slots **39**, **40** formed in the spacers **34**. As shown, the slot **39** is of a depth and width slgihtly greater than the slot **40**. When one wishes to remove and replace the slit-defining members **36**, **37**, the spring retainer **38** is shifted upwardly as seen in FIG. 2 until its lower end may be removed from the slot **40**. The spring retainer **38** is then removed from the slot member space and the slit members **36**, **37** may be removed and replaced. On assembly, the slit members **36**, **37** are positioned. The spring retainer is inserted first into the slot **39** and then into the slot **40**. The member **37** is cylindrical while the member **36** has enlarged end portions **42**, **43** which abut the surface **24** and the member **37**. These enlarged end portions maintain a central portion **44** of the member **36** spaced from the member **37** to define an accurate slit space **49** between them. The space **49** as shown is exaggerated in width for clarity of illustration. As suggested above, the member **37** may be a roller contact of the type designed for needle bearings.

In FIG. 4, enlarged perspective views of the members **36**, **36***a* are shown. The members **36**, **36***a* have end portions **42**, **43** and **42***a*, **43***a*, respectively, which are of an enlarged diameter with respect to the central cylindrical portions **44**, **44***a*. As suggested above, it is preferred that these end portions **42**, **43** be developed by electroplating a thin layer of material on a cylindrical member such as a needle bearing roller element. These end portions **42**, **43** maintain the central portions **44**, **44***a* in spaced relationship so that the central portions of the two members define a narrow precise slit indicated at **49'** on an enlarged and exaggerated scale.

A slightly modified slit structure is shown in FIG. 5. There, one of the slit-defining members is the member **37** and again it is a cylindrical member. A second slit-defining member **51** is provided which has a cylindrical central portion **52** and spaced eccentric camming portions **53**, **54**. The external eccentric and non-circular surfaces of these end portions **53**, **54** provide camming surfaces which, upon rotation of the member **51**, will provide a slit **60** of adjustable transverse dimension.

Although the invention has been described in its preferred form with a certain degree of particularity, it is understood that the present disclosure of the preferred form has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

What is claimed is:

1. In a mass spectrometer an ion source, an analyzer region, a collector, and slit assemblies respectively interposed between the source and the region and between the region and the collector, at least one of said slit assemblies including the improved combination comprising:

(a) a slit-supporting structure positioned across and transverse to an ion path, said structure-having a through aperture along the path;

(b) said structure including spaced surfaces extending transversely of the path and defining a member-receiving space therebetween;

(c) a pair of slit-defining members in said space and including central portions;

(d) one of said members having spaced enlarged end portions abutting the other of the members and maintaining the central portions in spaced relationship such that the central portions define an ion-beam delineating slit aligned with the aperture;

(e) said spaced surfaces locating said members longitudinally of the path and thereby orienting the members longituidnally;

(f) said structure including locator means defining an end of said member-receiving space;

(g) said locating means being abutted by a first of said members to orient the members transversely of the path and with respect to the aperture; and,

(h) said structure also including a retainer means biasing said members together and said first member against said locating means such that the members are positioned to close the aperture other than for the ion-beam delineating slit.

2. The spectrometer of claim 1 wherein the other of said members is cylindrical.

3. The spectrometer of claim 1 wherein said central portions are cylindrical.

4. The spectrometer of claim 1 wherein the spaced portions are cylindrical and axially aligned with the central portion.

5. The spectrometer of claim 1 wherein the spaced portions are eccentric.

6. The spectrometer of claim 1 wherein both members have spaced enlarged end portions.

7. A mass spectrometer comprising:

(a) an ion source;

(b) an analyzer region;

(c) a collector;

(d) slit structures respectively interposed between the source and the region and between the region and the collector;

(e) at least one of said slit structures including:

(i) an annular base plate surrounding and transverse to an ion path, said plate having a through aperture along the path;

(ii) a locator secured to said base plate;

(iii) a pair of spaced retaining plates secured to the base plate on opposite sides of said aperture and transverse to said locator;

(iv) a pair of slit-defining members interposed between said plates and including generally cylindrical central portions;

(v) one of said members having spaced enlarged end portions abutting the other of the members and maintaining the central portions in spaced relationship; and,

(vi) a spring retainer secured to said plates and biasing said members together and said one member against said locator.

8. A mass spectrometer comprising:

(a) an ion source;

(b) an analyzer region;

(c) a collector;

(d) slit structures respectively interposed between the source and the region and between the region and the collector;

(e) at least one of said slit structures including:

(i) a plate surrounding and transverse to an ion path, said plate having a through aperture along the path;

(ii) locator and retaining means secured to the plate and defining a member-receiving space aligned with said aperture;

(iii) a pair of slit-defining members in said space and including central portions;

(iv) one of said members having spaced enlarged end portions abutting the other of the members and maintaining the central portions in spaced relationship such that the central portions define an ion-beam delineating slit aligned with the aperture;

(v) said locating and retaining means including a locating surface abutted by a first of said members to orient the members with respect to the aperture, said locator and retainer means also including portions overlying segments of the members to maintain the orientation of the members longitudinally of the path; and,

(vi) a retainer means connected to said plate and biasing said members together and said first member against said locating surface such that the members are positioned to close the aperture other than for the ion-beam delineating slit and the slit is oriented transversely of the path by the retainer means and the locating surface.

9. The spectrometer of claim 8 wherein one of said members is cylindrical.

10. The spectrometer of claim 8 wherein said enlarged portions are cylindrical and axially aligned with the central portion of said one member.

11. The spectrometer of claim 8 wherein said enlarged portions are eccentric.

12. The spectrometer of claim 8 wherein both members have enlarged portions.

References Cited

UNITED STATES PATENTS

2,814,728	11/1957	Langsdorf	250—49.5
2,852,684	9/1958	Payne	250—41.9
3,187,179	6/1965	Craig et al.	250—41.9
3,230,362	1/1966	Davis et al.	250—41.9
3,238,371	3/1966	Furnas	250—105

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U.S. Cl. X.R.

250—105